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ESTABLISHMENT CRITERIA FOR VISUAL APPROACH SLOPE INDICATOR (VAS--ETC(U)
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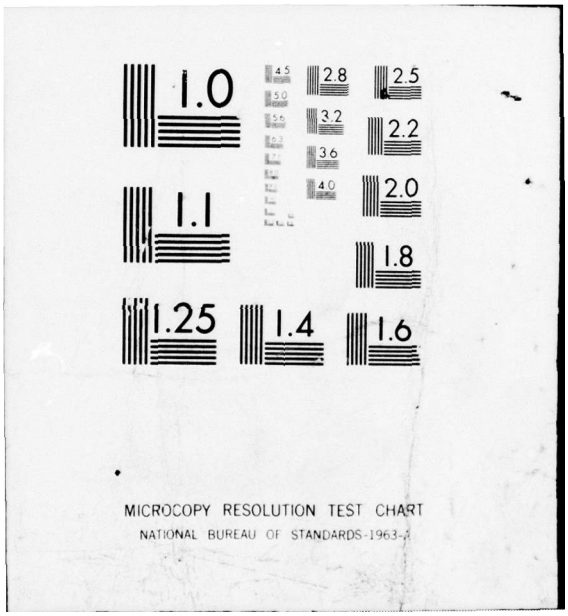
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REPORT NO. FAA-ASP-76-2

ESTABLISHMENT CRITERIA FOR VISUAL APPROACH SLOPE INDICATOR (VASI)

MAY 1977

U.S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Office of Aviation System Plans
Washington, D.C. 20591

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16. Abstract

This report develops revised establishment and discontinuance criteria for Visual Approach Slope Indicator (VASI) which provide Visual Flight Rules (VFR) guidance only. Criteria are based upon detailed benefit/cost methodology. This approach takes into account the number of aircraft landings by user class with variations depending upon whether or not the runway is equipped with an Instrument Landing System.

Benefits derived from a VASI are principally in the area of safety which are obtained by improved guidance during final VFR approaches.

Revised criteria require that a ratio value be computed for each of the three types of operations (air carrier, air taxi, and general aviation including military). The three ratios are then added to obtain a total ratio value, and this is multiplied by the runway utilization to obtain a net ratio value. If this net ratio value is equal to 1 or greater, then the runway is a candidate for a VASI.

In the short term, it is estimated that 590 runways now without a VASI will qualify. Over the next ten years, an additional 388 runways are expected to qualify for a VASI.

17. Key Words	18. Distribution Statement
Visual Approach Slope Indicator (VASI), Benefit/Cost, Net Ratio Value, Visual Flight Rules (VFR)	Document is available to the public through the Office of Aviation System Plans of the Federal Aviation Administration.

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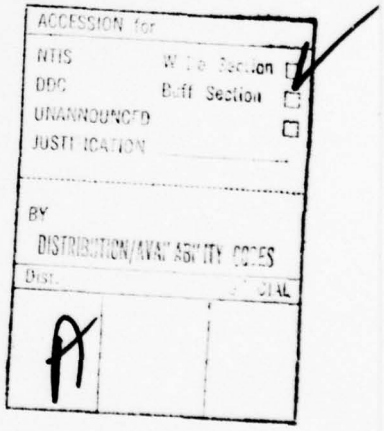

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EXECUTIVE SUMMARY

Previous Visual Approach Slope Indicator (VASI) criteria specified facility establishment at those airports which recorded 5,000 or more annual landings regardless of aircraft mix and discontinuance at those airports which recorded less than 3,000 annual landings on the runway it served.

This report develops revised establishment and discontinuance criteria for VASI's which provide Visual Flight Rules (VFR) guidance only. Criteria are based on a benefit/cost approach. This approach takes into account the number of aircraft landings by user class with variations depending upon whether or not the runway is equipped with an Instrument Landing System (ILS).

The revised criteria evaluate candidate locations by means of a two-phase approach:

Phase I - The revised criteria as published in Airway Planning Standard Number One, Order 7031.2B, require that a ratio value be computed for each of the three types of landing operations (air carrier, air taxi, and general aviation including military). The three ratios are then added to obtain a total ratio value, and this is multiplied by the runway utilization to obtain a net ratio value. If this net ratio value is equal to 1 or greater, then the runway is a candidate for a VASI. Revised criteria have been developed for the 2-bar; 2-box, 4-box, and 12-box, and Walker 3-bar; 6-box and 16-box.

Phase II - This detailed benefit/cost methodology will be used by FAA Headquarters to validate and rank candidate locations identified by Phase I and submitted as part of the annual Call for Estimates. The methodology used is outlined in this report (FAA-ASP-76-2).

Because the revised criteria raised the activity level required to qualify for candidacy, they are more stringent than the previous criteria. It is estimated that through FY 1978 the revised criteria would identify 590 candidates, 718 candidates less than the previous criteria. However, over the next 10 years, the number of potential candidates identified by the revised criteria is estimated at 978, which is only 341 less than the previous criteria. The budget impact of these 978 facilities is estimated at $42.05 million.

Discontinuance criteria have also been revised based on a similar two-phase approach. It is estimated that 47 existing VASI's are candidates for decommissioning under the revised criteria, which is 1 less than under the previous criteria. However, this includes VASI's installed under the Airport Development Aid Program (ADAP), which may not have met the previous Airway Planning Number One (APS-1) at the time of programming.

Benefits attributed to a VASI are primarily in the area of safety. These safety benefits were developed by analyzing the National Transportation Safety Board (NTSB) Accident/ Fatalities Reports and statistics for accidents which were determined to be avertable by a VASI. No benefits for time saved or improved efficiency were identified for quantification.

SECTION 1 - INTRODUCTION

The Visual Approach Slope Indicator (VASI) is a system of lights at the sides of a runway that gives visual descent guidance during final approaches for both day and night Visual Flight Rules (VFR) operations. Each light unit projects toward the approaching aircraft a beam of light having a white segment in the upper part of the beam and a red segment in the lower part. If the pilot of an airplane on final approach sees only red lights, he is undershooting the desired runway touchdown point; if only white, he is overshooting; if white downwind and red upwind, he is on course.

This report develops revised establishment and discontinuance criteria for a VASI based on benefit/cost analysis (Phase II) and net ratio value criteria (Phase I) which were empirically derived from Phase II.

VASI candidates will be evaluated by means of a two-phase approach:

Phase I - Net ratio value criteria are published in Airway Planning Standard Number One (APS-1) and used by the Federal Aviation Administration (FAA) regions along with Headquarters offices and services to identify airports that are candidates for the installation of a VASI.

Phase II - Upon submission of detailed cost data, airport activity, and runway utilization, a benefit/cost analysis will be conducted by FAA Headquarters personnel to validate and rank each candidate location submitted in response to the annual Call for Estimates. This validation will be concurrent with and be an input to the Interservice Working Group's selection of VASI candidates. The benefit/cost analysis will supplement the validation process but is not intended to affect the responsibilities of the operating services for the validation of candidates. Regional offices may use the benefit/cost analysis as outlined in this report to identify potential VASI candidates if they so desire.

Figure 1 depicts the typical VASI configurations.

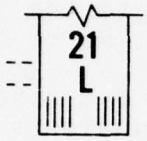
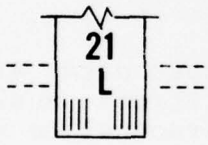
TYPE	SCHEMATIC	DAY VFR RANGE	COMMENTS
VASI-2 2 Bar 2 Box		3 Nautical Miles (5.6 kilometers)	Cannot be used by jet aircraft.
VASI-4 2 Bar 4-Box		4 Nautical Miles (7.4 kilometers)	FAA standard 2-bar VASI. Cannot be used by aircraft with high wheel-to-pilot-eye heights.
Walker 3 Bar 6-Box		4 Nautical Miles (7.4 kilometers)	FAA standard 3-bar VASI. Serves all aircraft types.
VASI-12 2 Bar 12-Box		5 Nautical Miles (9.3 kilometers)	Use at major airports requiring maximum boldness of signal. Cannot be used by aircraft with high wheel-to-pilot eye heights.
Walker 3 Bar 16-Box		5 Nautical Miles (9.3 kilometers)	Use at major airports requiring maximum boldness of signal. Serves all aircraft types.

Figure 1. VASI Configurations

SECTION 2 - PREVIOUS VASI ESTABLISHMENT CRITERIA

Previous establishment and discontinuance criteria for VASI, as defined in Airway Planning Standard Number One (APS-1), Order 7031.2B, dated September 20, 1974, are as follows:

A. Two-Bar VASI

1. Two-Box VASI

a. Establishment. When operationally required, any runway is a candidate for a two-box VASI provided that runway:

(1) is lighted;

(2) has 5,000 or more annual landings;

(3) has a minimum safety factor of 90 in accordance with Agency Order 8260.18A; and,

(4) is not used for large turbojet aircraft operations.

b. Discontinuance. A two-box VASI is a candidate for decommissioning when the number of annual landings is less than 3,000 on the runway it serves.

2. Four-Box VASI

a. Establishment. When operationally required, any runway is a candidate for a four-box VASI system provided that runway:

(1) is lighted;

(2) has 5,000 or more landings;

(3) has a minimum safety factor of 90 in accordance with Agency Order 8260.18A;

(4) is used for large turbojet aircraft operations; and,

(5) if equipped with an electronic glide slope, has 5,000 or more annual landings made on that runway by aircraft not equipped to receive electronic glide slopes.

b. Discontinuance. A four-box VASI on a runway on which large turbojet operations are conducted is a candidate for reduction to a two-box VASI when the turbojet aircraft operations are discontinued and not forecast to be resumed. A four-box VASI on a runway with an electronic glide slope is a candidate for decommissioning when the number of annual landings by aircraft not equipped to receive electronic glide slope is less than 3,000 on that runway.

3. Twelve-Box VASI

a. Establishment. Any runway at a major international airport is a candidate for a twelve-box VASI provided that:

(1) the airport is eligible for, or has installed, a four-box VASI; and,

(2) the airport has an unusual safety requirement which is identified, substantiated, and justified in a staff study.

b. Discontinuance. A twelve-box VASI is a candidate for reduction to a four-box VASI when no unusual safety requirement exists to justify its retention.

B. Walker Three-Bar VASI

1. Walker Six-Box VASI

a. Establishment. Any runway is a candidate for a Walker Six-Box VASI provided that runway:

(1) is eligible for, or has installed, a four-box VASI;

(2) does not have an electronic glide slope installed or programmed; and,

(3) has operations conducted with the B-747, DC-10, L-1011, stretch DC-8, or C5A aircraft.

b. Discontinuance. A Walker Six-Box VASI is a candidate for reduction to a four-box VASI when operations using B-747, DC-10, L-1011, stretch DC-8, and C5A are discontinued on that runway and not forecast to be resumed. When an electronic glide slope is installed on a runway with a Walker Six-Box VASI, that VASI shall be reduced to a four-box VASI.

2. Walker Sixteen-Box VASI

a. Establishment. Any runway at a major international airport is a candidate for a Walker Sixteen-Box VASI provided the runway:

(1) is eligible for, or has installed, a twelve-box VASI;

(2) does not have an electronic glide slope installed or programmed; and,

(3) is used for operations of the B-747, DC-10, L-1011, stretch DC-8, or C5A aircraft.

b. Discontinuance. A Walker Sixteen-Box VASI is a candidate for reduction to a twelve-box VASI when operations with the B-747, DC-10, L-1011, stretch DC-8, and C5A are discontinued on that runway and not forecast to be resumed. When an electronic glide slope is installed on a runway with a Walker Sixteen-Box VASI, that VASI shall be reduced to a twelve-box VASI.

SECTION 3 - REVISED VASI ESTABLISHMENT AND DISCONTINUANCE CRITERIA

The net ratio value VASI criteria (Phase I) developed in this report replace the previous criteria that were published in Airway Planning Standard Number One. The format of these new criteria is a change from the previous criteria in that a summation will be required of ratio values that are based on the number of landings by user class (air carrier, air taxi, general aviation, and military). VASI candidates identified by this procedure will be further examined by a site-specific benefit/cost analysis (Phase II).

A. Establishment Criteria

The Phase I criteria identify candidates for budget submissions which are submitted in response to the annual Call for Estimates. Under these criteria, a factor called the net ratio value is computed by the following procedure.

A runway having any combination of air carrier, air taxi, and general aviation activity is a candidate for submission for Phase II benefit/cost analysis for a VASI if it satisfies the net ratio value criteria described below.

A ratio value for each user class is computed for the airport as a whole, and the three ratios are added to obtain a total ratio value. This ratio value is then multiplied by the runway utilization (percentage of all landings accounted for by the particular runway) to obtain a net ratio value. If the net ratio value is equal to or greater than 1, then the location is a candidate.

The net ratio value computation takes the following form:

User Class			
Air Carrier:	$\frac{\text{Recorded (AC) Landings}}{\text{Qualifying (AC) Landings}}$	=	x.xx
Air Taxi:	$\frac{\text{Recorded (AT) Landings}}{\text{Qualifying (AT) Landings}}$	=	x.xx
General Aviation:	$\frac{\text{Recorded (GA + Mil) Landings}}{\text{Qualifying (GA + Mil) Landings}}$	=	x.xx
	Total Ratio Value	=	x.xx

Total Ratio Value x Runway Utilization = Net Ratio Value

Recorded Landings - This refers to the airports actual number of total landings by user class. If this traffic information is not actually recorded, estimates as shown on FAA Form 5010-1 will be acceptable.

Qualifying Landings - This is dependent upon whether or not the runway is ILS-equipped and is taken from the following table:

	Non-ILS		ILS	
User Category	2-Box	4-Box	2-Box	4-Box
Air Carrier (AC)	5,500	6,000	*	*
Air Taxi (AT)	7,500	8,500	25,000	28,000
General Aviation (GA) & Military (Mil)	12,500	14,000	16,500	18,500

*On an ILS-equipped runway, the air carrier ratio value is zero. Air carriers are ILS-equipped and the VASI serves only as a visual backup for the pilot during final approach.

For the runway that has an ILS and is being considered for a VASI system, a safety benefit factor has been incorporated into the number of qualifying landings shown on the above table.

The safety benefits accrued by aircraft using a VASI installed on an ILS runway are as follows:

Air Carrier - 0 percent of benefits attributed to a VASI installed on a non-ILS runway

Air Taxi - 30 percent of benefits attributed to a VASI installed on a non-ILS runway

General Aviation - 75 percent of benefits attributed to a VASI installed on a non-ILS runway

These reductions were made in order not to double count the safety benefits provided by an ILS. Although air carriers are ILS-equipped and given a choice they would normally make an ILS approach, the VASI serves only as a visual backup

for the pilot during final approach. Under this premise, it was estimated that no safety benefits can be attributed to a VASI installed on an ILS runway since the ILS criteria developed in Report No. FAA-ASP-75-1 assumed that all ILS-equipped aircraft will make instrument approaches. Analysis of the FAA report, "Commuter Air Carrier Operators as of September 1974," shows that approximately 70 percent of the air taxi fleet is ILS-equipped. This indicates that an air taxi landing on an ILS runway would derive 30 percent of the benefits it derives while landing on a non-ILS-equipped runway. A survey of the general aviation fleet shows that approximately 25 percent of these aircraft are ILS-equipped. This indicates that a general aviation aircraft landing on an ILS runway would derive 75 percent of the benefits it derives while landing on a non-ILS-equipped runway.

The airport runway utilization factor may be obtained by one of two methods. If the aircraft activity is counted by runway, then the percentage use of each runway can be calculated. The percentage use that applies to the VASI candidate runway will be used as the runway utilization factor. Since the actual aircraft activity data by runway is normally not available, the runway utilization factor is then obtained from Table 1. In the row corresponding to the number of active runways at the airport, the busiest runway is assumed to have the first percentage of all landings, the next busiest runway is assumed to have the second percentage, and so on. After all airport runways have been ranked according to activity, the percentage obtained from Table 1 for the VASI candidate runway will be used as the runway utilization factor.

TABLE 1

Runway Utilization
(for use if actual data is not available)

Number of Runways *	Percentage of Total Landings											
	Busiest Runway									Least Busy Runway		
2	70	30										
4	50	25	15	10								
6	30	20	15	15	10	10						
8	30	20	15	10	10	5	5	5				
10	25	15	10	10	10	10	5	5	5	5		
12	20	15	10	10	10	5	5	5	5	5	5	5

*Number of runways refers to the ends of all active hard-surface runways

B. Discontinuance Criteria (Phase I)

To determine whether a runway meets the discontinuance criteria, proceed in the same fashion as for net ratio value criteria described in Section 3, paragraph A. If the net ratio value is less than 0.5, then the runway becomes a candidate for decommissioning. The decommissioning shall be justified by a detailed benefit/cost study.

C. Revised VASI Criteria

Revised establishment and discontinuance criteria for VASI are defined in change 10 to Airway Planning Standard Number One (APS-1), Order 7031.2B, as follows:

1. Establishment

a. Two-Bar VASI

(1) Two-Box VASI. When operationally justified, any runway is a candidate for a two-box VASI provided that the runway:

(a) has a net ratio value greater than 1.0, as computed by use of the methodology outlined in Section 3A; and,

(b) is primarily used by general aviation aircraft.

(2) Four-Box VASI. When operationally justified, any runway is a candidate for a four-box VASI provided that the runway:

(a) has a net ratio value greater than 1.0, as computed by use of the methodology outlined in Section 3A; and,

(b) is primarily used by turbojet aircraft operations.

(3) Twelve-Box VASI. Any runway at an international airport where there is a stated planning requirement listed in ICAO documents 8733 and 8755 is a candidate for a twelve-box VASI provided that the runway is eligible for, or has installed, a four-box VASI.

b. Walker Three-Bar VASI

(1) Walker Six-Box VASI. Any runway is a candidate for a Walker Six-Box VASI provided that the runway:

(a) is eligible for, or has installed, a four-box VASI;

(b) does not have an electronic glide slope installed or programmed; and,

(c) is regularly used by the B-747, C5A, or similar aircraft with high wheel-to-eye height.

(2) Walker Sixteen-Box VASI. Any runway at an international airport where there is a stated planning requirement listed in ICAO documents 8733 and 8755 is a candidate for a Walker Sixteen-Box VASI provided that the runway:

(a) is eligible for, or has installed, a twelve-box VASI;

(b) does not have an electronic glide slope installed or programmed; and,

(c) is regularly used by the B-747, C5A, or similar aircraft with high wheel-to-eye height.

2. Discontinuance

a. Two-Bar VASI

(1) Two-Box VASI. A two-box VASI is a candidate for decommissioning when it has a net ratio value less than 0.5, as computed by use of the methodology outlined in Section 3B. The decommissioning shall be justified by a benefit/cost study.

(2) Four-Box VASI. A four-box VASI is a candidate for decommissioning when it has a net ratio value less than 0.5, as computed by use of the methodology outlined in Section 3B, and there is no straight-in nonprecision instrument approach to the runway it serves. The decommissioning shall be justified by a benefit/cost study.

(3) Twelve-Box VASI. A twelve-box VASI is a candidate for reduction to a four-box VASI when the stated ICAO requirement is withdrawn.

b. Walker Three-Bar VASI

(1) Walker Six-Box VASI. A Walker Six-Box VASI is a candidate for reduction to a four-box VASI when operations using B-747, C5A, or similar aircraft with high wheel-to-eye height are discontinued on that runway and not forecast to be resumed, or when an electronic glide slope is installed on that runway.

(2) Walker Sixteen-Box VASI. A Walker Sixteen-Box VASI is a candidate for reduction to a twelve-box VASI when operations using B-747, C5A, or similar aircraft with high wheel-to-eye height are discontinued on that runway and not forecast to be resumed, or when an electronic glide slope is installed on that runway.

NOTE: Criteria for the twelve-box, two-bar VASI and the Walker Sixteen-Box, Three-Bar VASI are incorporated in Airway Planning Standard Number One to meet ICAO commitments.

D. Benefit/Cost Analysis (Phase II)

VASI candidates identified by the above criteria will be validated by FAA Headquarters using the benefit/cost (B/C) technique described in this report (See examples in Appendix A). FAA offices, services, and regions will submit the following data required for this validation with their response to the annual Call for Estimates:

1. Recorded number of operations by user class (AC, AT, GA, Mil);

2. Number of runways at the airport;

3. Whether an ILS is installed or programmed for the candidate runway;

4. Number and types of VASI's already installed or programmed for other runways at the same airport; and,

5. Runway utilization, if available.

If the B/C ratio obtained from this validation is 1 or greater, when the life-cycle costs used include both initial investment and annual operations and maintenance (O&M), then the runway can be considered for the establishment of a VASI. If the B/C ratio obtained from this validation is less than 1, when the life-cycle costs used include only annual O&M, then

the runway can be considered for the decommissioning or reduction to a lesser configuration of the VASI. Installation costs are considered sunk when a VASI location is being considered for decommissioning.

Although Phase I is based on typical two-box and four-box costs, actual costs of the proposed system (initial investment only) submitted in response to the annual Call for Estimates will be used to compute the B/C ratio for each of the five VASI systems.

SECTION 4 - TYPICAL VASI COSTS

A VASI system is configured as either a two-bar or three-bar. The two-bar includes the two-box, four-box, and twelve-box types, whereas the three-bar includes the six-box and sixteen-box types. Figure 2 depicts a typical VASI-4 installation. All light bars are located at the same distance from the runway edge. The first bar is usually located around 500 feet (152.4 meters) from the end of the runway with a 700-foot (213.4 meters) separation between the first-second and second-third.

VASI costs include the costs of the equipment and its installation, annual operation and maintenance, and flight inspection as shown in Table 2. The discounted life-cycle costs have been computed based on a 15-year investment period and a 10 percent discount rate as shown in Table 3.

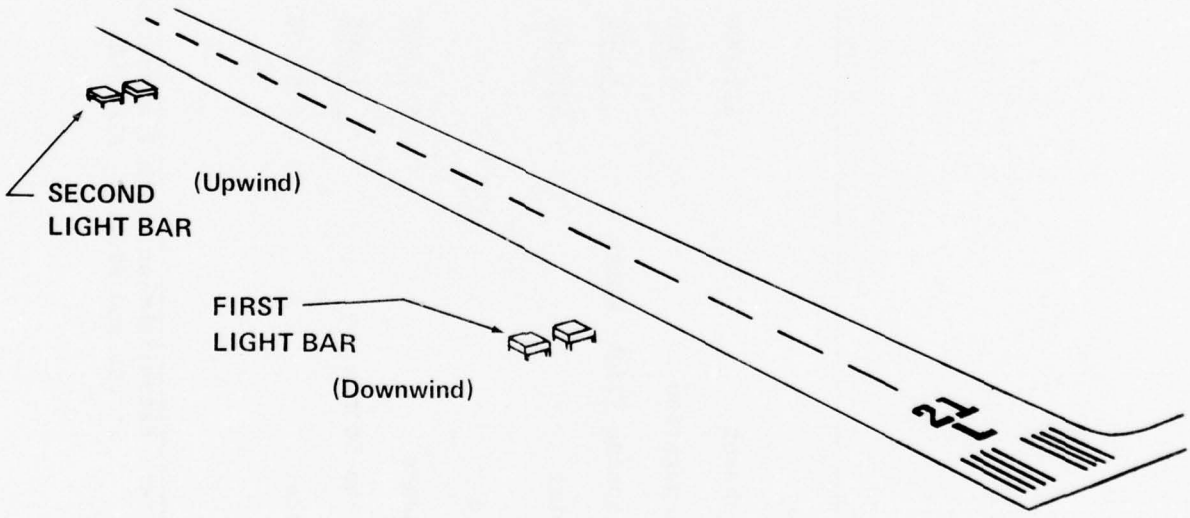


Figure 2. Typical VASI-4 Installation

TABLE 2

Costs of VASI

Cost Item	2-Box	4-Box	6-Box	12-Box	16-Box
Investment					
Establishment	$21,000	$31,000	$39,000	$50,000	$63,000
Site Preparation	8,500	8,500	8,500	8,500	8,500
Commissioning Flight Check	1,500	1,500	1,500	1,500	1,500
Total	$31,000	$41,000	$49,000	$60,000	$73,000
Annual O&M					
Maintenance	$ 3,900	$ 3,900	$ 3,900	$ 3,900	$ 3,900
Stocks and Stores	1,400	1,400	1,400	1,400	1,400
Total	$ 5,300	$ 5,300	$ 5,300	$ 5,300	$ 5,300

Data Source: Establishment, Site Preparation, Flight Check, and Maintenance - AAF-130/250
Stocks and Stores: ALG-240

TABLE 3

VASI - Discounted Life-Cycle Costs

Cost Item	Cost	Discount Factor		15-Year Discounted Costs
2-Box				
Investment	$31,000	1.000 *		$ 31,000
Annual O&M	5,300	7.607 **		40,000
			Total	$ 71,000
4-Box				
Investment	$41,000	1.000 *		$ 41,000
Annual O&M	5,300	7.607 **		40,000
			Total	$ 81,000
6-Box				
Investment	$49,000	1.000 *		$ 49,000
Annual O&M	5,300	7.607 **		40,000
			Total	$ 89,000
12-Box				
Investment	$60,000	1.000 *		$ 60,000
Annual O&M	5,300	7.607 **		40,000
			Total	$100,000
16-Box				
Investment	$73,000	1.000 *		$ 73,000
Annual O&M	5,300	7.607 **		40,000
			Total	$113,000

* 1.000 = Present worth at year zero
** 7.607 = Present worth year 15 at 10% discount

Data Source: Establishment, Site Preparation, Flight Check and Maintenance - AAF-130/250
Stocks and Stores - ALG-240

SECTION 5 - METHODOLOGY FOR DETERMINING VASI BENEFITS

The benefits derived from the establishment of a VASI system are principally in the area of safety which are obtained by improved guidance during final VFR approach. This improved guidance is considered to be responsible for the prevention of some approach accidents that otherwise might have occurred during VFR conditions. The ground proximity warning system (GPWS), which incorporates a mode to alert pilots to excessive sink rate on approach, was evaluated for its possible contributions to safety during final approach. It was determined that the GPWS did not contribute to the provisions of a uniform descent approach and consequently had no impact on the benefits derived from the establishment of a VASI. The safety benefits in this report are based on Report No. FAA-AVP-75-2 (Reference 9), which analyzed the National Transportation Safety Board data base of aircraft accidents for the nine-year period 1964-1972.

The benefit/cost methodology for identifying potential VASI systems includes only benefits attributable to reduced landing accidents. Economic benefits such as those associated with a community development were considered, but since they were not presently quantifiable, they are not included in the report. There are no VASI benefits attributable to reduced flying time.

The detailed methodology is as follows.

A. Landing Accidents

The landing accident subset identified by the FAA report consists of 18,602 accidents, of which 11,389 accidents occurred while attempting visual approaches. Of the 11,389 accidents, 54 were air carrier, 287 were air taxi, and the remaining 11,048 were general aviation. Landing accidents are defined as accidents which occurred either while the aircraft was approaching the airport for a landing (including executing a missed approach) or rolling along the runway just after touchdown. For visual approaches, it includes the flight path from the point of entry into the traffic pattern to the point of touchdown. Landing accidents where the cause was aircraft failure or pilot impairment are not included in the landing accident category. The following table shows how the landing accidents were distributed among user classes.

Landing Accidents by User Class 1964-1972	
Air Carrier	124
Air Taxi	444
General Aviation	18,034
	18,602

B. Landing Fatalities

The landing fatality subset identified by the FAA report consists of 1,627 fatalities from the 18,602 accidents. Most of the air carrier fatalities, 300 out of 552, and most of the general aviation, 764 out of 988, occurred during visual approaches. The following table shows how the fatalities were distributed among user classes.

Landing Fatalities by User Class 1964-1972	
Air Carrier	552
Air Taxi	87
General Aviation	988
	1,627

C. Fatalities/Accident

The following table shows how the number of fatalities per accident was distributed among the user classes.

Fatalities/Accident by User Class 1964-1972	
Air Carrier (552/124)	4.45
Air Taxi (87/444)	0.20
General Aviation (988/18,034)	0.05

D. Landings/Accident

The cumulative number of local and itinerant landings for the nine-year period 1964-1972 was extracted from the FAA Air Traffic Activity, CY-73. The following table shows how the landings/accident were distributed among user classes.

Landings/Accident by User Class 1964-1972

Air Carrier (42,000,000/124)	338,709
Air Taxi (9,000,000/444)	20,270
General Aviation (162,000,000/18,034)	8,983

E. Avertable Accidents

Analysis of the data indicates that 1,983, or 11 percent, of the 18,034 general aviation accidents were undershoots on final approach or collisions with the ground, water, or an object while the aircraft was flaring. Almost all of these accidents occurred in VFR weather. It is hypothesized that these accidents might have been averted if a visual glide slope such as that provided by a VASI had been available.

The following table illustrates the percentage of visual approach accidents by user class that might have been averted if a VASI had been available.

Percentage of Avertable Accidents by User Class 1964-1972

Air Carrier (17/124)	14%
Air Taxi (62/444)	14%
General Aviation (1,983/18,034)	11%

F. Landings/Avertable Accident

A comparison of the landings/accident to the percentage of the avertable accidents yields the following table.

Landings/Avertable Accident by User Class 1964-1972	
Air Carrier (338,709/0.14)	2,419,350
Air Taxi (20,270/0.14)	144,785
General Aviation (8,983/0.11)	81,663

Accident Costs

Accident costs include loss or injury to human life and loss or damage to aircraft. The value of human life was estimated at $300,000 for each aircraft accident fatality based on non-Warsaw payment data. Injuries are classified as serious and minor. Aside from the number of accidents and injuries, very little is known about the extent of injuries, the average length of hospitalization, medical costs, etc. Fromm (Reference 13) estimated that the average seriously injured passenger requires about six months to fully recuperate from the accident, with a per-injury cost of about $45,000. For minor injuries, assuming that the victim is incapacitated for one month, the per-injury cost is estimated at $6,000. Rand (Reference 12) has compiled statistics on the rates of fatalities and injuries, aggregated over all types of accidents, over the period 1964-1972. The statistics show that for every fatality there is a corresponding serious and minor injury. The average damage factor for each aircraft category involved in accidents was estimated by NTSB (References 2 and 3) to be:

Air Carrier	0.3
Air Taxi	0.5
General Aviation	0.5

Average aircraft replacement costs are estimated to be $6 million for an air carrier aircraft, $150,000 for an air taxi aircraft, and $50,000 for a general aviation aircraft. The equation used to compute aircraft accident costs is as follows:

$$AC = (F/A)(VL) + (DA)(VA) + (I/A)(VSI + VMI)$$

where:

AC = Accidents costs
F = Fatalities
I = Injuries
A = Accident
VL = Value of life
DA = Damage to aircraft
VA = Value of aircraft
VSI = Value of serious injuries
VMI = Value of minor injuries

The following table shows the average cost per accident by user class as computed using the data and equation presented above.

Average Cost per Accident by User Class 1964-1972

Air Carrier:	[4.45($300,000) + 0.3($6,000,000) + 4.45(45,000 + 6,000)] = $3,361,950
Air Taxi:	[0.20($300,000) + 0.5($150,000) + 0.20(45,000 + 6,000)] = $145,200
General Aviation:	[0.05($300,000) + 0.5($50,000) + 0.05(45,000 + 6,000)] = $42,550

Safety Benefits

Estimates of the safety benefits provided by a VASI through the prevention of visual approach landing accidents were developed by dividing accident costs (see preceding table) by the average number of avertable accidents (see table under paragraph F, Section 5, page 19). The following table illustrates the safety benefits of a visual approach landing provided by a VASI system.

Safety Benefits for Each Visual Approach Landing

Air Carrier ($3,361,950/2,419,350)	$1.39
Air Taxi ($145,200/144,785)	1.00
General Aviation ($42,550/81,663)	0.52

VASI safety benefits are a function of air traffic activity. Since air traffic is expected to increase throughout the next 15 years, net discount factors have been developed in Table 4 by multiplying OMB's discount factors by FAA's median forecast factors for 1975 to 1986 which were extrapolated to 1990. These net discount factors, summed over the next 15 years, are: air carrier = 9.449; air taxi - 9.450; general aviation - 10.929. The 15-year streams of discounted benefits per VASI landing, by user class, were obtained by multiplying the preceding table by the appropriate net discount factor. The results of these computations are shown in the following table.

Discounted 15-Year Benefits Associated with a VASI Landing	
Air Carrier: 9.449($1.39)	$13.13
Air Taxi: 9.450 ($1.00)	9.45
General Aviation: 10.929($0.52)	5.68

TABLE 4

Net Discount Factors

Year After Funding	10% Discount Factor	Aviation Growth Factor 1975-1990			Net Discount Factors for Benefits *		
		AC	AT	GA	AC	AT	GA
1	.909	1.053	1.036	1.070	.957	.942	.973
2	.826	1.093	1.070	1.118	.903	.884	.923
3	.751	1.122	1.137	1.217	.843	.854	.914
4	.683	1.160	1.168	1.316	.792	.798	.899
5	.621	1.196	1.198	1.393	.743	.744	.865
6	.565	1.231	1.227	1.462	.696	.693	.826
7	.513	1.273	1.284	1.541	.653	.659	.791
8	.467	1.314	1.311	1.583	.614	.612	.739
9	.424	1.345	1.364	1.612	.570	.578	.683
10	.386	1.375	1.389	1.673	.531	.536	.646
11	.351	1.412	1.413	1.736	.496	.496	.609
12	.319	1.447	1.437	1.787	.462	.458	.570
13	.290	1.474	1.484	1.834	.427	.430	.532
14	.263	1.501	1.506	1.889	.395	.396	.497
15	.239	1.540	1.549	1.931	.368	.370	.462
	7.607				9.449	9.450	10.929

*10% discount factor times growth factor

SECTION 6 - IMPACT ASSESSMENT

A. Establishment Criteria

To assess the impact of revising the previous criteria, a comparison was made in the following areas:

1. Runways with a Phase I Ratio Value of 1 or Greater - Year of First Occurrence

TABLE 5

Candidate Locations (FY-76 through FY-86)
Previous versus Revised Criteria

	FY-76	FY-77	FY-78	FY-81	FY-86	Total
2-Box						
Previous criteria	643	0	3	0	0	646
Revised criteria	317	10	15	71	81	494
4-Box						
Previous criteria	661	0	1	1	10	673
Revised criteria	215	16	17	69	167	484

Table 5 depicts the number of locations which meet the previous and revised VASI criteria for the first time. Examining the total number of VASI candidates through FY-86 shows that the revised two-box and four-box criteria are 23 percent and 28 percent more stringent than the previous criteria.

2. Benefit/Cost Distribution of Candidate Locations. Table 6 depicts the benefit/cost ratio distribution for all candidate locations. If a comparison is made between the candidates identified by the previous criteria and the new Phase II benefit/cost analysis, 152 and 189 two-box and four-box VASI's would be installed in locations that are not

economically justified. This would result in an unwarranted expenditure of $14.66 million of Government funds. The "false alarm rates" for the revised criteria are near 0 percent for both the two-box and four-box. A false alarm consists of candidate locations that meet Phase I criteria but fall short of meeting a benefit/cost ratio of 1 or more.

TABLE 6

Benefit/Cost Distribution of Candidate Locations (FY-86)
Previous versus Revised Criteria

	2-box		4-box	
	Previous	Revised	Previous	Revised
1.0 or more	489	489	471	471
.90 - .99	31	5	33	13
.80 - .89	39	0	32	0
.70 - .79	32	0	45	0
.60 - .69	27	0	31	0
.50 - .59	8	0	22	0
.40 - .49	10	0	13	0
.30 - .39	6	0	9	0
.20 - .29	4	0	10	0
.10 - .19	0	0	5	0
0 - .09	0	0	2	0
Total B/C Distribution	646	494	673	484

The "nonidentification" rate for the revised criteria is 0 percent for the two-box and four-box. Nonidentification consists of candidate locations which have a benefit/cost ratio of 1 or more but fail to be identified by the Phase I criteria.

B. Discontinuance Criteria

To assess the impact of the discontinuance criteria, a benefit/cost ratio was computed for each one of the existing VASI systems included in the National Flight Data Center (NFDC) ILS/VASI data base. The total number of VASI's in operation as of July 1975 was 423, of which 119 are two-box. The remaining 314 are four-box, six-box, or twelve-box; however, for criteria purposes, these will be considered as four-box.

The results of the discontinuance analysis are as shown in Table 7, which compares the number of existing VASI locations identified by the previous and revised criteria that are candidates for decommissioning. In FY-76, the previous criteria identify 14 percent of the two-box VASI locations as candidates for decommissioning, whereas the revised criteria identify 13 percent. Again, in FY-76, the previous and revised criteria identify 10 percent of the four-box VASI locations as candidates for decommissioning.

Even though the revised establishment criteria are more restrictive than the previous criteria, the locations identified for discontinuance by both criteria are essentially the same. This occurs because the previous criteria identified the discontinuance level as 0.6 of the establishment level, whereas the revised criteria identify the discontinuance level as 0.5 of the establishment level.

The discontinuance analysis examined all the VASI's that are in operation including both F&E- and ADAP-funded systems. VASI candidates who fail to qualify under the previous criteria, as required for F&E funding, are sometimes funded by the ADAP program or an air carrier. As a result, even under the previous criteria, there are a number of VASI locations which are candidates for decommissioning.

TABLE 7

Existing VASI Locations
Which Are Candidates for Decommissioning

	FY-76	FY-77	FY-78	FY-79	FY-80
2-Box					
Previous criteria *	17	16	16	11	7
Revised criteria **	16	15	14	10	5
4-Box					
Previous criteria *	31	30	29	26	19
Revised criteria **	31	31	30	26	18

* Previous decommissioning criteria are based on an activity less than 3,000 annual landings on the candidate runway.

** Revised decommissioning criteria are based on a benefit/cost ratio less than 0.5 for the candidate runway.

SECTION 7 - SENSITIVITY ANALYSIS

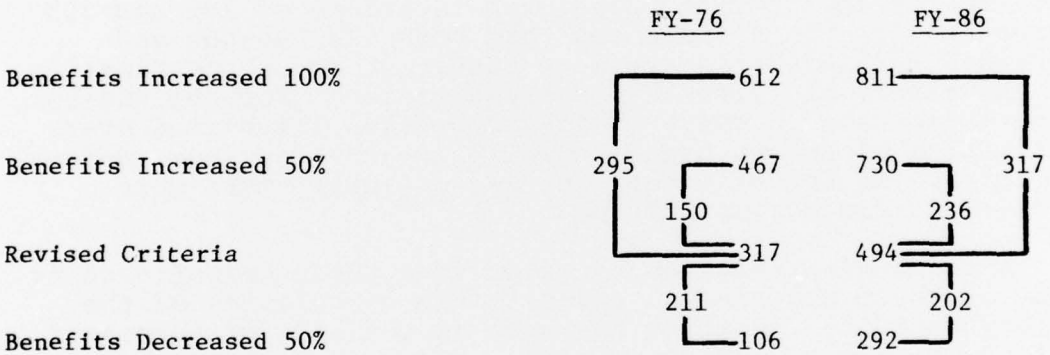
VASI criteria were developed by calculating benefit/cost ratios for the 890 airports included in the data base. This data base consists of airports which record 100 or more annual instrument approaches. Although the analysis does not look at all the airports in operation, it provides a good representation of how the criteria influence the selection of economically viable candidate locations. These ratios consist of two components which can be varied to observe the sensitivity of the benefit/cost ratio over time. The two components are safety benefits and VASI life-cycle costs.

A. Safety Benefits

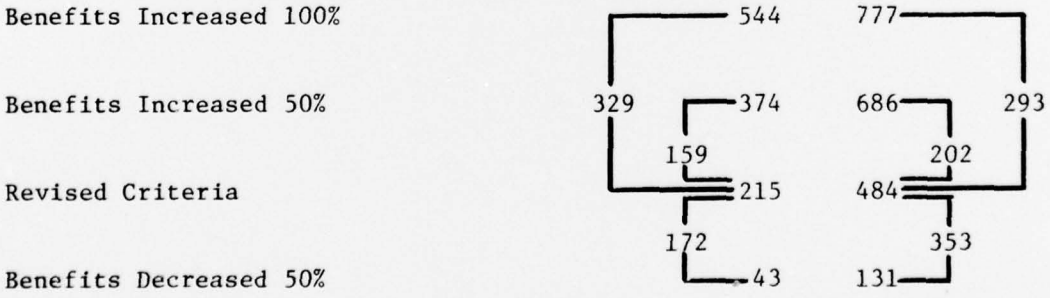
TABLE 8

Candidate Locations Identified by Varying Safety Benefits

2-Box VASI



4-Box VASI



NOTE: Increased and decreased benefits are relative to the safety benefits developed in the revised criteria.

Table 8 illustrates how a variation of the safety benefit influences the number of VASI candidates. Variations of the safety benefit were made as follows: (1) Increase benefits by 50 percent over revised criteria; (2) Increase benefits by 100 percent over revised criteria; and, (3) Decrease benefits by 50 percent from revised criteria. A 50 percent and 100 percent increase in safety benefits in FY-76 increases the number of two-box candidates by 150 and 295 and the number of four-box candidates by 159 and 379, respectively. Conversely, if the safety benefits are decreased by 50 percent in FY-76, there is a reduction in the two-box and four-box candidate locations of 211 and 172, respectively. This suggests that the two-box criteria in FY-76 are approximately one and one-half times more sensitive to underestimation of the safety benefits than overestimation. However, the four-box criteria are about equally sensitive to an equal increase or decrease in the level of safety benefits.

In FY-86, a 50 percent and 100 percent increase in safety benefits increases the number of two-box candidates by 236 and 317 and the number of four-box candidates by 202 and 293, respectively. When the safety benefits are decreased by 50 percent in FY-86, there is a reduction in the two-box and four-box candidate locations of 202 and 353, respectively. This indicates that both the two-box and four-box VASI criteria are more sensitive to underestimation of the safety benefits than overestimation. For the two-box, underestimation is over two times more sensitive than overestimation of safety benefits while for the four-box, underestimation is approximately one and one-half times more sensitive than overestimation.

A conclusion that can be drawn from these comparisons is that if there has been an error in the calculation of the safety benefit, the error has been on the side of increased safety.

B. Life-Cycle Costs

TABLE 9

Candidate Locations Identified
by Varying VASI Life-Cycle Costs

2-Box

	FY-76	FY-86
Revised Criteria	317	494
Costs Increased 50%	137 / 211 / 180	113 / 381 / 204
Costs Increased 100%	106	290

4-Box

	FY-76	FY-86
Revised Criteria	215	484
Costs Increased 50%	128 / 172 / 87	230 / 254 / 353
Costs Increased 100%	43	131

NOTE: Increased costs are relative to the costs developed in the revised criteria.

Table 9 illustrates the number of locations that are identified by varying the VASI life-cycle costs. Locations identified by the revised criteria were compared to the following conditions: (1) Increase life-cycle costs by 100 percent over revised criteria; and (2) Increase life-cycle costs by 50 percent over revised criteria. A 50 percent and 100 percent increase in life-cycle costs in FY-76 decreases the number of two-box candidates by 137 and 211 and the number of four-box candidates by 128 and 172, respectively. However, a 50 percent and 100 percent increase in life-cycle

costs in FY-86 decreases the number of two-box candidates by 113 and 204 and the number of four-box candidates by 230 and 353, respectively. This suggests that both the two-box and four-box VASI criteria are very sensitive to increases in their life-cycle costs. The four-box VASI criteria appear to be more sensitive by FY-86 to an increase in life-cycle costs.

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APPENDIX A

Application of VASI Benefit/Cost Criteria

This appendix gives illustrations of how to determine if a runway is a candidate for the installation of a VASI. It also illustrates how the FAA Headquarters uses the benefit/cost technique to validate and rank candidate locations submitted for possible inclusion in the budget.

The following calculations are for a two-box and a four-box VASI at two ficticious airports.

Two-Box

Runway 31 at the ASP airport has been identified as a possible candidate for a two-box VASI. It is required to provide vertical guidance over a featureless terrain for existing nonprecision straight-in approach.

A. Phase I

1. Determine if runway has an ILS: No.

2. Determine percent runway utilization: 50%. This utilization was determined from Table 1, Percent Runway Utilization, using four runways and that this is the airport's first VASI.

3. Determine the number of landings by user category.

User Category	Landings
Air Carrier	0
Air Taxi	1,000
General Aviation	42,000
Military	0

4. Select appropriate Phase I establishment criteria and calculate ratio value. Since there are no turbojet landings, the two-box, non-ILS runway is appropriate.

User Category			Ratio Value
Air Carrier:	$\frac{0}{5,500}$	=	0.00
Air Taxi:	$\frac{1,000}{7,500}$	=	0.13
General Aviation:	$\frac{42,000}{12,500}$	=	3.36
		Ratio Value =	3.49

Multiply ratio value by runway utilization to obtain net ratio value:

$$3.49 \times 0.50 = 1.75$$

Since 1.75 is greater than 1, the runway is a candidate for a two-box VASI.

B. Phase II

1. Determine life-cycle costs of a two-box VASI. The life-cycle costs are depicted in Table 3 at $71,000.

2. Calculate discounted benefits associated with VASI landings.

a. Multiply landings by appropriate safety benefit. From the table on page 21, AC = $13.13, AT = $9.45, GA = $5.68.

User Category	Benefits
Air Carrier: 0	$ 0
Air Taxi: 1,000($9.45)	9,450
General Aviation: 42,000($5.68)	238,560
	$248,010

b. Multiply benefits by runway utilization.

$$\$248,010 \times 0.50 = \$124,005$$

3. The benefit/cost ratio thus is $124,005/71,000 = 1.75. Since 1.75 is greater than 1, the runway qualifies for a two-box VASI.

NOTE: This location meets the Phase I and Phase II requirements for a four-box VASI; however, since it has no turbojet operations, it does not qualify for the establishment of a four-box VASI.

Four-Box

Runway 35 at the AVP airport has been identified as a possible candidate for a four-box VASI. It is required to provide vertical guidance over flat, featureless, unlighted terrain.

A. Phase I

1. Determine if runway has an ILS: No.

2. Determine percent runway utilization: 70%. This utilization was determined from Table 1, Percent Runway Utilization, using two runways and that this is the airport's first VASI.

3. Determine the number of landings by user category.

User Category	Landings
Air Carrier	0
Air Taxi	3,000
General Aviation	22,000
Military	0

4. Select appropriate Phase I establishment criteria and calculate ratio value. Since there are no turbojet landings, the four-box, non-ILS runway is appropriate.

User Category			Ratio Value
Air Carrier:	$\frac{0}{6,000}$	=	0.00
Air Taxi:	$\frac{3,000}{8,500}$	=	0.35
General Aviation:	$\frac{22,000}{14,000}$	=	1.57
		Ratio Value =	1.92

Multiply ratio value by runway utilization to obtain net ratio value:

$$1.92 \times 0.70 = 1.35$$

Since 1.35 is greater than 1, the runway is a candidate for a four-box VASI.

B. Phase II

1. Determine life-cycle costs of a four-box VASI. The life-cycle costs are depicted in Table 3 at $81,000.

2. Calculate discounted benefits associated with VASI landings.

a. Multiply landings by appropriate safety benefit. From the table on page 21, AC = 13.13, AT = 9.45, GA = 5.68.

User Category	Benefits
Air Carrier: 0	$ 0
Air Taxi: 3,000($9.45)	28,350
General Aviation: 22,000($5.68)	124,960
	$153,310

b. Multiply benefits by runway utilization.

$153,310 x 0.70 = $107,317

3. The benefit/cost ratio thus is $107,317/81,000 = 1.35. Since 1.35 is greater than 1, the runway qualifies for a four-box VASI.